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knowledge, we can interpret only as those of a stegocephalan, but no hard parts have been found to show us what the animal was like. We may hope, yes, almost expect, that future exploration will show us stegocephalans in rocks of Devonian age, and when those are found it is possible that they will embrace types which will be decisive as to mammalian ancestry. Yet how slight are the chances of such discovery is shown by one fact concerning our knowledge of the mesozoic mammals. Nearly half of the known species of these were found in a bed of clay in southern England, the whole deposit measuring forty feet in length, ten in breadth and five inches in thickness.

J. S. KINGSLEY.

TUFTS COLLEGE.

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*THE RELATION OF PHYSICAL GEOGRAPHY TO OTHER SCIENCE SUBJECTS.**

IN geography we have not as yet reached that stage when vague spheres of influence give place to definite territorial boundaries. Our science is still unorganized, its frontiers are not demarked and the dividing lines of its provinces are not yet drawn. My subject compels me to take up a number of questions still so unsettled that I can hardly hope to suggest even a *modus vivendi* which in this time of boundary disputes will be acceptable in all its details to many besides its author.

At least in America, we shall all agree that physical geography is not identical in its limits with what our English friends term physiography. It is not a summation of our knowledge of nature. Such was the older physical geography, and valuable as was its view over the entire kingdom of science, it was found impracticable as an educational instrument. With its string of disconnected chapters on the elements of physics, chemistry, astronomy, geology, botany, zoology, and ethnology, concluding perhaps with a chapter on precious stones, it is no wonder that there was sometimes applied to it the sacred definition of a circle whose center is everywhere and whose circumference is nowhere. And yet to many a boy it gave his only world-view, his only touch with nature. When Huxley spoke of it, this Erdkunde, as 'a peg on which the greatest quantity of useful and entertaining scientific information can be suspended,' it was not in disparagement; for he termed it one of the essentials of a liberal education.

Physical geography has often been treated as though it were equivalent to the 'science of geography,' as Strachey has defined it, or as synonymous with the 'general geography' of the Germans. But its note is neither the introduction of the causal notion nor a topical treatment of the subject. It is not to be set over against either descriptive or a real geography. Surely the adjective in the phrase may well have a restrictive influence. Either 'physical' as here used is equivalent to 'natural,' in which case our science reverts to physiography, or else it limits the subject to physical as distinct from biologic phenomena. Accepting this restriction, we may set the divisions of geography in the following scheme:

1. Chorographic geography.

2. Physical geography, with its subheads of the geography of the planet, the geography of the air, the geography of the sea, and the geography of the land.

3. Biotic geography, the distribution of animals and plants.

4. Anthropic geography, the geography of man.

The chorographic member, dealing with position, direction and dimension, is the rudiment from which the entire body of geography has developed. The map, its first product, remains its chief vehicle of

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expression. I can only stop here to notice that in education this member has but recently passed its culmination. The leading American geography of twenty-five years ago, on account of its many excellencies called by Col. Francis Parker in 1894 'the best geography in English ever issued,' touched the highwater mark of topography. Its map questions on the continent of South America required a knowledge by the pupil of 9 capes, 48 cities and 30 rivers. The boy who knew his lesson in Guyot could tell you that the leading affluents of the Orinoco are the Venture, Coroni, Auraca, Meta, and Guaviari rivers. To-day the pupil in Frye escapes from South America with a burden of but 1 cape, 11 rivers and 25 cities, a total of 37 place-names of these three kinds, as against the 87 which his father learned in Guyot.

The space saved by this shrinkage is largely given in recent texts to the physical side of the subject. Our 'advanced' or 'complete' school geographies open with a compend of physical geography, and a wealth of physiographic material is scattered with free hand throughout the text. In the high-school our science is commonly reviewed as a distinct study.

In its opening chapter on the geography of the planet, physical geography borrows freely from astronomy. Its view-point, however, is geocentric. Its astronomy is planetary, not sidereal. No fact nor theory is introduced except in direct and important relations to the earth.

The geography of the air is practically conterminous from our standpoint with meteorology. It makes drafts on the elementary principles of physics. It everywhere introduces the causal notion. Both the physical and the purely geographical contents are indispensable, and it would be futile to attempt to isolate either.

Under whatever name meteorology is taught, it should have a large place in school programs, so many and so vital are our relations to this ocean of air at whose bottom we dwell, so fundamental are its effects on land forms, so immediate are its controls of the distribution of life. Few studies offer so good facilities for scientific observation. The apparatus it requires is inexpensive. The daily reading of its instruments, the search for the causes of to-day's weather changes and the effort to predict those of to-morrow, give training of high value. The school becomes in a way a member of a corps of scientific observers, since it receives each morning the records of the work of the Weather Service to compare with its own. Indeed, so valuable is meteorology as an educational instrument that it surely will win place as a distinct study in the high-school.

The geography of the sea is of minor importance to our subject, and we may pass at once to the pith of physical geography, the geography of the land, the science of land forms, or geomorphology, as it is technically and rather lengthily termed. It is here that our science presents the largest range and variety of phenomena. It is here that its relations to life are most direct and complex. So central is this portion of geography that all other divisions may be grouped about it in subordinate relations and the whole thus attain organization and unity. The geography of the planet, the sea and the air are prerequisite to the geography of the land, since it is by the action of the mobile envelopes that the forms of the lithosphere have been sculptured, while the applications of these physical conditions lead directly into the biotic and anthropic divisions.

It is not strange, therefore, that with the organization of the science the study of land forms has taken a large place. It is called by Penck 'the main part of geography proper.' The masterly treatise of de Lap-

parent 'Leçons de géographie physique,' is geomorphology pure and simple from beginning to end. Is this distinguished geologist of France biased by his profession? Well, here then is Boulangier, who in his 'Traité de géographie physique' reassures his readers that the author is *not* a geologist, and still defines his subject as 'the methodical and rational study of the surface forms of the planet.' Wagner excludes from our science both anthropic and biotic geography, while Supan admits, of the two, only the latter. Davis has given us under the name of physical geography the most complete and luminous treatise on land forms in the language, in which, however, there are everywhere introduced applications of physical conditions to the life of plant, animal and man—matter of great value usually omitted in European texts.

So rapidly, so lusty and so big has geomorphology grown that it has been suggested by Professor Dryer that it aims to play the part of the young cuckoo and oust from the nest the remainder of the geographical brood. It is scarcely of age, and yet the science of land forms has already rejuvenated geology and rationalized the domain of geography. Geomorphology is the child of geology and geography, and it inherits its father's strength and its mother's beauty. From geography it brings the 'half artistic' description of the features of the earth and their distribution; from geology it brings the reasoned processes of their formation. Just now it seems to be an educational question as to which of the parents the child should be given in keeping. Should land forms be taught in high-schools chiefly as physical geography or as geology? This is perhaps the most important question raised by my subject. It involves the relations of the two sciences and their educational values.

The overlap-land of geomorphology may be claimed by geology with as sure a right as any of its other provinces, such as paleontology. It was by geologists that it was explored. The Committee of Fifteen accredits the advance in scientific geography the last few decades to the work of geographical societies, and to a limited extent this is surely true, in Great Britain especially. And yet, as one of the foremost British geographers, H. R. Mill, has stated, it is 'the recent work of three geologists, Penck, Davis and Lapparent,' that 'has brought this aspect of the relation between geography and geology boldly to the front.' Without question it is by geologists that the science of land forms has been created. The list of the founders and leaders of the American school of physiographic geology, whose primacy is so generally admitted, is quite too long for mention, but I cannot omit the names of Powell, Lesley, Gilbert, Davis, Dutton, McGee, Chamberlin, Russell and Tarr. How large, also, have been the contributions of foreign geologists, such as Ramsey and Geikie, Richthofen, Suess, Heim and Walther, Noe, Margerie and Lapparent. If some of these, as Penck and Davis—to the latter of whom Lapparent justly attributes 'the preponderating influence in the development of the new conceptions'—are officially known as professors of physical geography, they belong, notwithstanding, to the brotherhood of the hammer.

The attention of geology was early diverted from the study of land forms, but it brings on its return a wealth of material which compensates amply for its absence. The reports of the U. S. Geological Survey contain a body of physiographic information and doctrine unequaled in the publications of any scientific society. Our recent State surveys show the splendid results of the application of the methods of the geologist to the study of reliefs, as in the work of Salisbury in New Jersey, Calvin in Iowa, and Marbut in Missouri. The new geology describes the forms of the land with a pre-

cision and detail hitherto unknown. It refers them to their places in a genetic classification. It assigns them to their order in an evolutionary life history. Furthermore, it uses them as the older geology used fossils and the succession of strata; it reads in reliefs the story of the geological past. It not only explains the present by the past, but it also reveals the past by means of the present. The physiognomy of a region may be the record of a large part of its geological history. While the geomorphologist requires the special equipment and competence of the geologist, it is no less true that the geologist must now perforce be a geomorphologist.

In the geological courses now offered in American universities land forms have a large and increasing place. It is given under different names, but with essentially the same content. In some, as in the University of Wisconsin, applications to human life are included, an essentially geographic subject. In the higher American schools, with one notable exception, Harvard, it is only in the laboratories and lecture rooms of the department of geology that the student of land forms can obtain adequate training. "The surest foundation," as Richthofen has said, "for the study of geography is geology, in its whole compass, as being the only means to an understanding of the earth's surface." Geology thus retains possession of the field both in research and in advanced instruction.

As Davis has pointed out, land forms are functions of three variables—structure, process and time. The first of these, structure, together with the causes which have produced it, is undoubtedly a geological subject, and it is from geology that the geomorphologist must here draw all his data. Process has always been treated under dynamic geology, and yet as a part of geophysics, as treating of agents now in action upon the earth, it belongs also to geography. The cycle of time, 'that unmeasured part of eternity,' during which process produces upon structure the evolving series of topographic forms may well be claimed by the science which deals with the past history of the earth. The position of geologists is well stated by Sir Archibald Geikie in answer to the argument of Sir Clements Markham, President of the Royal Geographic Society, who had drawn the line between the two sciences at the dawn of history, excluding geology from the study of the changes of the earth's surface since that time. "Since geology may be regarded as the history of the earth, whatever is necessary for the elucidation of that history will be claimed by the geologists as part of their domain. Only as they understand what is going on at the present day can they understand what took place in past time. If you take away from the geologist the study of all that is taking place now, and maintain that this study is not geology but physical geography, he will answer, 'I do not care what you call it. I must be at liberty to investigate the processes which are operating now, in order that I may be able to explain what has happened in past time.'"

The dependence of geography on geology often has been compared with that of painting or sculpture upon anatomy. But the simile is far from complete, unless the former science is content to remain descriptive only, dealing with the delineation of external form. For the reliefs of the land must be studied and classified not primarily or chiefly as to form, but by structure and genesis. So soon as the description of the features of the earth's surface and their distribution yields to an inquiry into their origin, the line is passed which divides the -graphy from the -logy.

These questions are not perhaps without some practical outcome. The organization of these sciences, and the theoretic limits between them in the field of research in-

fluence our high-school courses sooner or later. It is in this somewhat remote field that the deciding factor may be found which shall at last settle the matter as to whether the physiognomy of the land be chiefly taught in secondary schools as geology or as geography.

Fortunately certain criticisms of each science have been laid by recent educational progress. In view of our present text-books, physical geography can no longer be called 'hash' nor can geology now be termed dry and dull. Neither of these earth sciences is dull except to the dullard. So large is the place of land forms in both the new physical geography and the new geology, that it is now a question of approach to a common content of knowledge.

Let me claim for geology the easier path of approach, the clearer and more natural method of presentation, the greater coherence and the vaster and more inspiring view.

The geological path is that of process. It studies the agents now in operation with the resulting structures and forms that are produced at each stage of the evolutionary cycle. It thus binds together cause and effect as closely as possible. It admits an inductive treatment based on the observation of common things. The geographical path is normally that of form. In many of our physical geographies this has been avoided and the geological approach frankly taken in its stead, this portion of the subject becoming an epitome of dynamic geology. It is perhaps owing to the personal equation that to me the method of classification by form seems somewhat miscellaneous and scrappy. It throws together, for example, phenomena as diverse genetically as the glacial plains of Iowa, the base plains of Russia, the lava fields of Oregon, the old lake floor of the Red River of the North, and the coastal plains of the Gulf. Supan is compelled by his method of arrangement to take up the glacier under three of the five great divisions of his Physical Geography—under the atmosphere where the general description is given, under the Dynamics and under the Morphology of the Lands. There is no question of the value of such a classification to the advanced student. Is it as good for the high-school pupil as that of geology, which, in the case of the glacier, for example, draws from meteorology the climatic conditions, and from geography the description of its features, and then proceeds forthwith to treat of its work as a geological agent and of the land forms thus produced? It is perhaps because of the easier path and better method which geology offers that in the courses at Cornell University, N. Y., a year in it precedes the year offered in physical geography.

Geology also gives what a painter would term atmosphere to this common body of knowledge. It sets it in perspective. To an extent this is also done by physical geography, and I confess that I have been surprised to see how readily students of recent texts, such as Davis's, gain a realization of the time-element in the geographical cycle, though they have had no geological preparation. But these conceptions are enlarged and vivified by the detailed study of geologic time. It is well to know the geography of the Allegheny mountains, it is better still to know their morphogeny, but it is best of all to set the whole in geological perspective, to view their folding in the remote close of the Palæozoic, and their long waste during the Middle Age of geology to a plain whose gradual dissection after uplift and during subsequent cycles has sculptured these mountains to the forms we behold to-day.

It is also something to set to the credit of geology that it teaches the history of organic evolution. Perhaps we have not as yet learned to paint the panorama of creation so that its salient features are not

smothered in detail. But to know what the earth is we must know what the earth has been. The story of the planet and the life it has sustained is prerequisite to a complete understanding of the earth sciences and of the life sciences as well.

As an educational instrument geology has the advantage of concentration and homogeneity. If, like mathematics or physics, it lacks the warm human interest, the applications of geography to human life, yet its current is not shoaled by division into numerous channels. If either physical geography or geology must be omitted from our crowded high-school courses, let it not be geology, the more fundamental, the more coherent, the more educative of the two.

What then should be the place and sequence of the earth sciences in secondary programs? Can they be arranged so as to include the outlines of all, and yet without repetition? It seems to me that certain changes are desirable to secure this end. I should like to see nature study so enlarged in the lower grades that the common physiographic processes early become familiar. There is an evident trend toward the enlargement of the physical geography with which our advanced geographies are now introduced. To me this seems the proper place for the study, but while the treatment of all essential forms and processes which bear directly on the life and work of man may be expanded, all matter irrelevant to this should here be omitted. I should like to see the areal and descriptive geography which follows so enlarged that it will take in the American high-school the place it holds in the German *Realschulen* and *Gymnasia*. Each geographic unit, each region of our country, each national domain may then be treated thoroughly in all departments of the science. With the physical environment everywhere made basal, we need not fear to give anthropic geography the largest possible place. It may be that much might be brought in which a strict definition of geography would exclude. But with due selection of material, with grasp of principles, with historic perspective, and especially with a thorough knowledge of physiographic controls, the wise teacher of geography can afford to take as his motto, I consider nothing alien to myself that relates to man. The extension of anthropic geography, however, cannot be brought about by discussion, or criticism, or the writing of text-books. It must come in precisely the same way as has the extension of physical geography—by scientific research. It awaits the masters who will some time do for the sciences relating to man what geology is doing for the science of land forms.

The proper place, then, for physical geography is a place preliminary to the areal geography which applies its principles and consequences to special regions. To review it later as a separate study would then seem unnecessary. Instead, let the course in the earth sciences be concluded by meteorology and geology. The earth sciences may thus be so closely articulated as to form the vertebral column of secondary scientific instruction. So close is their touch with human life, so thorough and comprehensive is their discipline, so simple, so natural, so rational, and so real is their culture, that their extension only awaits their connection into one continuous line of study.

William Harmon Norton.
Cornell College, Iowa.

Professor Fraas on the Aqueous vs. Æolian Deposition of the White River Oligocene of S. Dakota.

A special expedition of the United States Geological Survey into the Bad Lands of South Dakota was led by N. H. Darton, of the Survey, assisted by J. B.